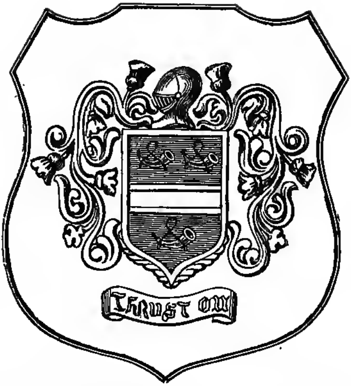
ar
17994

THE

UNIVERSAL METRIC SYSTEM.

ALFRED COLIN, M. E.



Robert Henry Thurston

A Gift to
Cornell University Library
1903

Cornell University Library
arV17994

The universal metric system :

3 1924 031 230 034
olin,anx

Cornell University Library

The original of this book is in
the Cornell University Library.

There are no known copyright restrictions in
the United States on the use of the text.

http://www.archive.org/details/cu31924031230034

THE
UNIVERSAL METRIC SYSTEM:

PREPARED ESPECIALLY FOR

CANDIDATES FOR SCHOOLS OF SCIENCE,
ENGINEERS, AND OTHERS.

BY

ALFRED COLIN, M. E.,
PRINCIPAL OF A PREPARATORY SCIENTIFIC SCHOOL.

NEW YORK:
D. APPLETON AND COMPANY,
549 & 551 BROADWAY.
1876.

D

Entered, according to Act of Congress, in the year 1876,
By D. APPLETON & CO.,
In the Office of the Librarian of Congress, at Washington.

THE following pages present a simple exposition of the Metric System, no attempt at any historical or critical sketch having been made. Numerous problems have been added — some containing valuable data — and, after careful reading, it is hoped that no book employing the System will present the least difficulty.

A. C.

NEW YORK, *March*, 1876.

THE UNIVERSAL METRIC SYSTEM.

Formerly every nation, and almost every village, had a particular set of measures, for the word *System* cannot be applied to units taken at random. Evidently commerce could only be a loser from such a diversity of methods of measurement, and, besides, no accuracy was possible. The originators of what is known as the *French Metric System* had in view the removal of all these difficulties.

The *Metric System* is called *French* because every system bears the name of the nation which introduced it, and until this system becomes *Universal*, or *International*, it will be styled *French*.

Scarcely can any one unhesitatingly answer, according to the methods usually adopted, such questions concerning the reduction of quantities as the following:

How many feet, yards, or poles, are there in 5 miles?

How many acres are there in 5 square miles?

To render such questions easy of solution, even to persons but little skilled in arithmetic, was the aim of the originators of the *Universal Metric System*, as they had not only France but the civilized world in view when framing their system.

The units of this system are :

1. The METRE for the unit of measure of *length.*
2. " SQUARE METRE and the ARE " *surface.*
3. " CUBIC METRE and the STERE " *volume.*
4. " LITRE " *capacity.*
5. " GRAMME " *weight.*

Unfortunately, we cannot add here a sixth name for the unit of *money*, consequently all our commercial necessities but the last can be referred to these *five* units. However, as these may prove too small or too large, we have *multiples* and *submultiples* (as well as their *doubles* and *halves* for the convenience of small traders), which are formed by prefixing the *five* above words with the following for their multiples :

Deca, ...	meaning	10.
Hecto, ...	"	100.
Kilo, ...	"	1,000.
Myria, ...	"	10,000.

These *four* names are taken from the Greek.

And by prefixing them to the following words for their *submultiples :*

Deci, ...	meaning	$\frac{1}{10} = 0{\cdot}1.$
Centi, ...	"	$\frac{1}{100} = 0{\cdot}01.$
Milli, ...	"	$\frac{1}{1000} = 0{\cdot}001.$

The last *three* are derived from the Latin.

Consequently, only *twelve* words are necessary to express any quantity in this system.

From the metre we obtain the following :

Multiples.—Decametre, hectometre, kilometre, myriametre.

Submultiples.—Decimetre, centimetre, millimetre.

From the litre :

Multiples. —Decalitre, hectolitre, kilolitre, myrialitre.

Submultiples.—Decilitre, centilitre, millilitre.

From the gramme :

Multiples.—Decagramme, hectogramme, kilogramme, myriagramme.

Submultiples. —Decigramme, centigramme, milligramme.

This system, based on our decimal system of numeration and notation, was adopted in France in 1799, but only became compulsory, to the exclusion of all others, since 1840 (and is sometimes for this reason called *legal*). Almost all the nations of the globe have adopted it. It was legalized in England in 1864, in the United States in 1866. It is employed in most scientific works, and to come into common use in this country requires but to be adopted by the Government in its official transactions.

THE UNIT OF LENGTH.

The unit of length is the *metre* (*μέτρον*, measure), which *is equivalent to the ten-millionth* $\left(\frac{1}{10{,}000{,}000}\right)$ *part of the distance from the pole to the equator.*

The distance from the pole to the equator is the quarter of the meridian. Hence,

		Metres.
From the pole to the equator there are		10,000,000.
From one pole to the other	"	20,000,000.
In a great circle or a meridian	"	40,000,000.

Here we meet with the only objection to the system. Is the distance from the pole to the equator exactly measured? No; and it cannot be, and, should it ever be, it would vary as taught by geology and astronomy. Then, why has such an unsatisfactory unit been chosen? Because nothing in the universe is everlasting, and the earth, notwithstanding its great changes, will outlive its inhabitants. Besides, provided a unit be adopted and kept as a standard in the archives of nations, all the conditions are satisfied, and the beauty and simplicity of the fundamental principles apply to it.

One metre = 39·3707904 English inches.

Hence the following table :

	Metres.		Inches.	
Myriametre, or	10,000	=	393,707·904	= 6·21 miles.
Kilometre,	1,000	=	39,370·7904	= 3,280 ft. 10 in.
Hectometre,	100	=	3,937.07904	= 328 ft. 1 in.
Decametre,	10	=	393·707904	= 32·8 ft.
Metre,	1	=	39·3707904	= 3·28 ft., almost 40 in.
Decimetre,	0·1	=	3·9370790	= almost 4 in.
Centimetre,	0·01	=	0·3937079	
Millimetre,	0·001	=	0·0393707	

The reduction to English measures is easy, when the English tables are known.

The following table is self-explanatory:

Millimetres.	Centimetres.	Decimetres.	Metres.	Decametres.	Hectometres.	Kilometres.	Myriametre.
1							
10	1						
100	10	1					
1,000	100	10	1				
10,000	1,000	100	10	1			
100,000	10,000	1,000	100	10	1		
1,000,000	100,000	10,000	1,000	100	10	1	
10,000,000	1,000,000	100,000	10,000	1,000	100	10	1

We find that 1 metre = 10 decimetres = 100 centimetres = 1,000 millimetres.
" " 1 myriametre = 10 kilometres = 100 hectometres = ...

The *Standard Metre*, kept in the National Archives in Paris, is a rod of platinum, which is only exact when at the temperature of 0° centigrade, the point at which ice melts.

The materials of which metres are manufactured, as well as the care taken in making them, depend on their destination.

For measuring dry goods they are generally wooden rods, with only ten divisions answering to the decimetres.

By architects, engineers, draughtsmen, etc., only half a metre (50 centimetres), or rather a double decimetre (20 centimetres), with the millimetres divided into two parts (corresponding to 0·0005 metre), is used, and this is made of brass, ivory, or box-wood.

For the use of artisans and others, a folding metre of ten divisions, each fold corresponding to one decimetre, is found convenient, and each decimetre is divided into centimetres and millimetres. This metre is made of box-wood, but more generally of brass, and sold at a trifling cost.

By surveyors, tape-lines and chains of 10 metres in length are used.

The *decametre* (10 metres) and the *hectometre* (100 metres) are only employed by surveyors in their calculations. It is more convenient to say 10, 20, 30 metres than 1, 2, 3 decametres, and 400, 500, 600 metres than 4, 5, 6 hectometres.

The *kilometre* (1,000 metres) is used as the unit of distance, and along roads and railways there are *kilometric poles* or *stones*.

The *myriametre* (10,000 metres) is hardly ever used, it being inconveniently large (6·21 miles).

The *decimetre* (0·1 metre) is frequently used, but it is still more common to say 10, 20, 30 centimetres than 1, 2, 3 decimetres.

The *centimetre* (0·01 metre) is the most common submultiple of the metre.

The *millimetre* (0·001 metre) is very generally made use of; for delicate work like machinery it is the unit, and 654 written on a drawing means 0·654 metre. Carpenters, masons, etc., employ the centimetre as their unit.

There are no measures smaller than the millimetre; but we count by tenths, hundredths, thousandths, etc., of a millimetre, when precision requires It is not usual to write 0·012½ metre, but rather 0·0125 metre.

There is no need of giving rules for reading and writing lengths expressed in metres, as *these rules are essentially the same as those of the decimal fractions and numbers.*

For instance, 12,345·675 metres may be read:

1 myriametre, 2 kilometres, 3 hectometres, 4 decametres, 5 metres, 6 decimetres, 7 centimetres, and 5 millimetres.

Or, 12 kilometres, 345 metres, and 675 millimetres, or in any other way we may choose.

The reduction of French to English measures, and conversely, is easily accomplished.

$$1 \text{ kilometre} = \frac{39{\cdot}37079 \times 1{,}000}{12 \times 3 \times 5\frac{1}{2} \times 40} = \frac{39{,}370{\cdot}79}{63{,}360} = 0{\cdot}621383 \text{ mile.}$$

Conversely—

$$1 \text{ mile} = \frac{1}{0{\cdot}621383} = 1{\cdot}6093149 \text{ kilometre.}$$

The same result is directly reached from—

$$\frac{12 \times 3 \times 5\frac{1}{2} \times 40}{39{\cdot}37079 \times 1{,}000} = 1{\cdot}609 \ldots \text{ kilometre.}$$

THE UNIT OF SURFACE.

The unit of surface is the *square metre; it is the area contained within a square each of whose sides is one metre long.*

Its multiples and submultiples, as well as their surfaces, are :

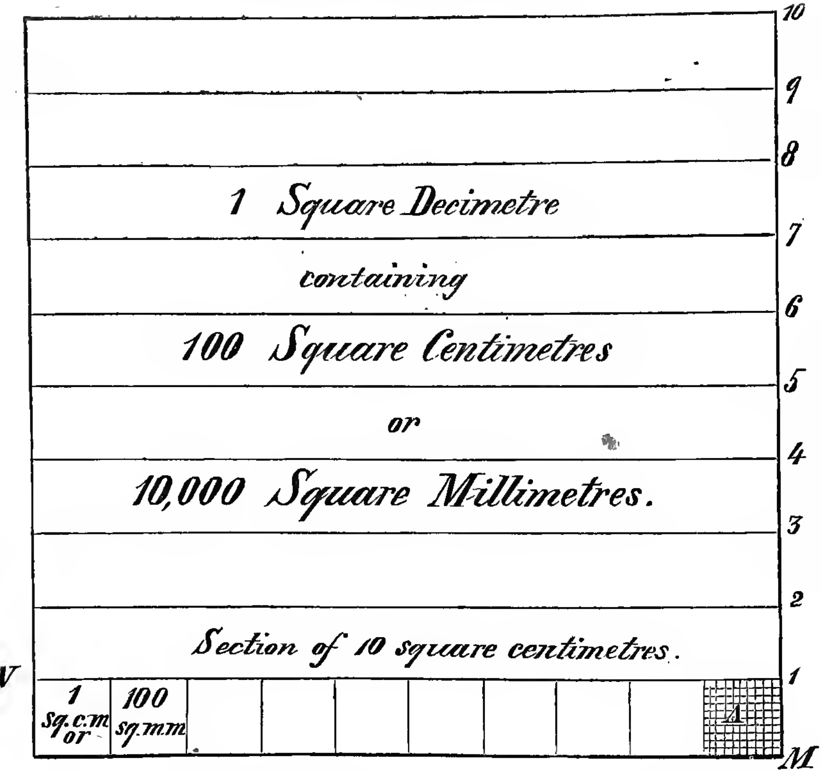
Square	myriametre	=	$10{,}000^2$	=	100,000,000	sq. metres.
"	kilometre	=	$1{,}000^2$	=	1,000,000	"
"	hectometre	=	100^2	=	10,000	"
"	decametre	=	10^2	=	100	"
"	METRE	=	1^2	=	1	"
"	decimetre	=	$0{\cdot}1^2$	=	0 01	"
"	centimetre	=	0.01^2	=	0·0001	"
"	millimetre	=	$0{\cdot}001^2$	=	0·000001	"

From which it appears that—

1. One square decametre contains 100 square metres, and not 10, as we might be tempted to believe.

2. One square decimetre is the $\frac{1}{100}$ part of the square metre, and not $\frac{1}{10}$. In fact, *every unit is equivalent to* 100 *of the next lower order.*

This must be kept well in view, and is better illustrated by the following diagram representing :



Although 1,000 metres make 1 kilometre, 1,000 square metres make but 10 square decametres. To prove it, let us in the above diagram suppose that the millimetres (0·001 metre) are metres. Then 100 square metres cover the square *A*, and 10 such squares or

(100 × 10 =) 1,000 square metres give but an horizontal section, or rectangle *M N.* But 100 square metres make, as seen in the diagram, 1 square decametre *A.* Hence, the whole rectangle *M N* is equivalent to 10 square decametres.

Furthermore, the whole square containing 10 such rectangles is equivalent to 100 × 100 = 10,000 square metres. Let us remark also that its side being 100 metres long or 1 hectometre, 1 square hectometre contains 10,000 square metres.

Here we must add that the numbers 10, 1,000, 100,000, 0·1, and 0·001, having no exact square roots (and, had they any, *those roots would not be multiples or submultiples of ten*), consequently these numbers are not multiples or submultiples of the square metre.

Hence, such a number as 35·75 square metres must be read 35 square metres 75 square decimetres. The 7 belongs certainly to an order ten times smaller than the units; however, it does not represent 7 squares whose sides are a decimetre long, but 7 rectangles of 1 metre in length and 1 decimetre in width. And the 5, representing hundredth parts of the square metre, are squares whose sides are equal to 1 decimetre.

Now, such a number as 19,875,643·46,789 square metres must be read *by separating it into periods of two figures, and adding one zero to the decimal, if odd.*

Kilo.	Hecto.	Deca.	Metres.	Deci.	Centi.	Milli.
19,	87,	56,	43·	46,	78,	90.

And is read: 19 sq. kilometres, 87 sq. hectometres, . . .

Remark.—We say 19 *square kilometres,* meaning 19 equal squares whose sides are each 1 kilometre long; while the expression 19 *kilometres square* means a square whose sides are each 19 kilometres long, and whose area is consequently (19 × 19 =) 361 square kilometres.

For surveying, a larger unit than the square metre is necessary, and this is the Are (Lat. *area,* surface), which *is the area contained within a square whose sides are* 10 *metres long;* or, more simply, *it is a square decametre.*

The demonstration of the square metre being understood, the multiples and submultiples of the *are* present no difficulty.

Let us state :

1. There are no such terms as *Decare* and *Kilare,* because these expressions would be equivalent :

Sq. Metres.
The *decare,* to 10 ares or 100 × 10 = 1,000.
The *kilare,* to 1,000 " 100 × 1,000 = 100,000.

And 1,000 and 100,000 have no exact square roots, and, should they have any, these would not be multiples of 10.

2. For the same reason *Deciare* and *Milliare* would also be equivalent :

The *deciare,* to $\frac{\text{are}}{10} = \frac{100}{10} = 10$ square metres.

The *milliare,* to $\frac{\text{are}}{1,000} = \frac{100}{1,000} = 0{\cdot}1$ square metre,

which numbers have no exact square roots. We have, therefore :

Myriare = 10,000 ares = 1,000,000 square metres, or
1 square kilometre, for $\sqrt{1{,}000{,}000} = 1{,}000$.

Hectare = 100 ares = 10,000 square metres, or
1 square hectometre, for $\sqrt{10{,}000} = 100$.

ARE = 1 are = 100 square metres, or
1 square decametre, for $\sqrt{100} = 10$.

Centiare = 0·01 are = 1 square metre, for $\sqrt{1} = 1$.

The following table explains itself, and shows that each unit is equivalent to 100 of the next lower order.

Square Millimetres.	Square Centimetres.	Square Decimetres.	Centiares or Square METRE.	ARES or Square Decametres.	Hectares or Square Hectometres.	Myriares or Square Kilometres.	Square Myriametre.
1							
100	1						
10,000	100	1					
1,000,000	10,000	100	1				
100,000,000	1,000,000	10,000	100	1			
10,000,000,000	100,000,000	1,000,000	10,000	100	1		
1,000,000,000,000	10,000,000,000	100,000,000	1,000,000	10,000	100	1	
100,000,000,000,000	1,000,000,000,000	10,000,000,000	100,000,000	1,000,000	10,000	100	1

The *square myriametre* is hardly ever employed, and then only to express the areas of countries or continents.

The *myriare* is never used, its equivalent the *square kilometre*, which is really the unit for large areas, being preferred.

The *hectare*, *are*, and *centiare*, are employed in surveying. Otherwise the words *square hectometre*, *square decametre*, and *square metre*, are made use of.

We may read indifferently 13,971 ares, 75 centiares, or 139 hectares, 71 ares, 75 centiares ; but we do not say 1 *myriare*, 39 *hectares*, ...

The reduction of French and English measures is easily accomplished : 1 are $= 393{\cdot}7^2$ square inches, which divided by 12^2 is converted into square feet, divided by $(12 \times 3)^2$ into square yards. For instance :

$$1 \text{ are} = \frac{393{\cdot}707^2}{(12 \times 3)^2} = \frac{154{,}757{\cdot}161}{1{,}296} = 119{\cdot}411 \text{ sq. yards ;}$$

$$\text{and } 1 \text{ are} = \frac{393{\cdot}707^2}{144 \times 9 \times 30\frac{1}{4} \times 40 \times 4} = 0{\cdot}0247114 \text{ acre ;}$$

because 1 acre = 4 roods × 40 poles × $30\frac{1}{4}$ square yards × 9 square feet × 144 square inches.

Conversely :

$$1 \text{ acre} = \frac{1}{0{\cdot}0247114} = 40{\cdot}46711 \text{ ares.}$$

The same approximate result is given by—

$$\frac{144 \times 9 \times 30\frac{1}{4} \times 40 \times 4}{393{\cdot}7^2} = \frac{6{,}272{,}640}{154{,}157} = 40{\cdot}6 \text{ ares.}$$

THE UNIT OF VOLUME.

The unit of volume is the *cubic metre*, which *is the volume of a cube whose edges are each one metre long.*

Its multiples and submultiples are :

				Cubic Metres.
Cubic myriametre	=	$10{,}000^3$	=	1,000,000,000,000
“ kilometre	=	$1{,}000^3$	=	1,000,000,000
“ hectometre	=	100^3	=	1,000,000
“ decametre	=	10^3	=	1,000
“ METRE	=	1^3	=	1
“ decimetre	=	$0{\cdot}1^3$	=	0·001
“ centimetre	=	0.01^3	=	0·000,001
“ millimetre	=	$0{\cdot}001^3$	=	0·000,000,01

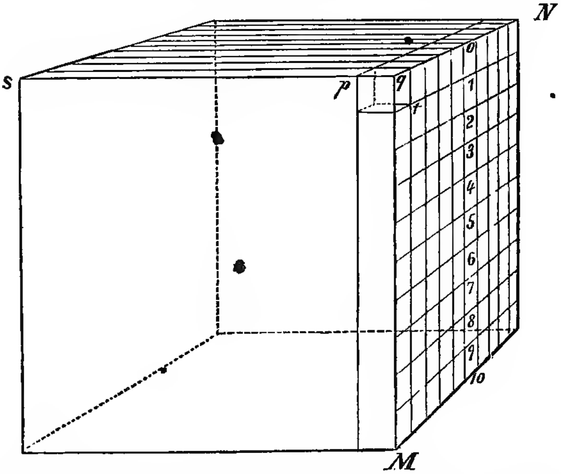
From which it is seen that 1 cubic decametre is equivalent to 1,000 cubic metres and not 10 ; that 1 cubic metre is equivalent to 1,000 cubic decimetres ; that 1 cubic decimetre is equivalent to 1,000 cubic centimetres, etc. ; in fact, that *every unit is equivalent to* 1,000 *of the next lower order.*

It is not usual to say *one cubic decametre,* as the mind comprehends better what is meant when we say 1,000 cubic metres.

The multiples of the cubic metre, being very considerable, are not used, and would only be available in astronomical measurements ; but, even then, more appropriate units are taken.

The submultiples of the cubic metre are much used. Let us, then, illustrate why 1 *cubic metre* = 1,000 *cubic decimetres.*

Supposing the following diagram to represent a cube, whose edges are each 1 metre long. The surface *M N*, being a square metre, contains 100 square decimetres ; but *p q* is one decimetre wide, or $\frac{1}{10}$ of *s q*,



and such a section as the parallelopipedon *p M N* contains 100 cubic decimetres, viz., 100 such cubes as *p t*. But, as the cube contains 10 equal sections, or parallelopipedons, we conclude that—

1 *cubic metre* = 1,000 *cubic decimetres.*

By a similar demonstration, if the diagram represent 1 cubic decimetre, we may prove that 1 cubic decimetre = 1,000 cubic centimetres, and, if it represent 1 cubic centimetre, this will contain 1,000 cubic millimetres.

A number such as 0·1 cubic metre is not 1 cubic decimetre, though $\frac{1}{10}$ of a cubic metre, but $\left(\frac{1,000}{10} =\right)$ 100 cubic decimetres. The number 0·25 cubic metre, though $\frac{25}{100}$ of a cubic metre, is $\left(\frac{25 \times 1,000}{100} =\right)$ 250 cubic decimetres.

From the above we conclude that, for reading a number expressed in cubic metres, we must *separate it into periods of three figures, and complete if necessary the decimal part by adding one or two zeros.* For instance: 1,456,743·4603752 cubic metres becomes—

Hecto.	Deca.	Metres.	Deci.	Centi.	Milli.
1,	456,	743·	460,	375,	200;

and is read: 1 cubic hectometre, 456 cubic decametres, 743 cubic metres, 460 cubic decimetres, 375 cubic centimetres, and 200 cubic millimetres.

The following table, containing only the submultiples of the metre (the multiples would require too much space), shows that for a number to be a multiple or submultiple of the cubic metre it must have a cubic root multiple or submultiple of 10.

Cubic Millimetres.			
1	Cubic Centimetres.		
1,000	1	Cubic Decimetres.	
1,000,000	1,000	1	Cubic METRE.
1,000,000,000	1,000,000	1,000	1

An error common to many writers on the Metric System is to call the unit of volume *stere* (from the Greek στερεος, solid). It had been originally intended to take it as the unit, but many names of the system have not become general, it being simpler to say 100 hectares than 1 myriare, 10,000 cubic metres than 10 cubic decametres. The word stere is only employed by dealers in wood for fuel, and

1 *decastere* represents 10 cubic metres;
1 *decistere* " $\frac{1}{10}$ of a cubic metre.

There are besides the *double stere*, *double decastere*, and *half decastere.*

The reduction of French to English measures is easily accomplished—

$$1 \text{ cubic metre} = 39{\cdot}37^3 \text{ cubic inches.}$$

$$1 \text{ cubic metre} \doteq \frac{39{\cdot}37^3}{12^3} = 35{\cdot}31481 \text{ cubic feet.}$$

Conversely:

$$1 \text{ cubic foot} = \frac{1}{35{\cdot}31481} = 0{\cdot}028314 \text{ cubic metre.}$$

The same result is given directly by—

$$\frac{12^3}{39{\cdot}37^3} = \left\{ \begin{array}{l} \text{28 cubic decimetres, 318 cubic centime-} \\ \quad\text{tres, 019 cubic millimetres.} \end{array} \right.$$

THE UNIT OF CAPACITY.

The unit of capacity is the *litre* (from λιτρα, a measure used among the Greeks), *which is equivalent to* 1 *cubic decimetre.*

The multiples and submultiples of the litre are :

Myrialitre	=	10,000	litres	=	10	cubic	metres.
Kilolitre	=	1,000	"	=	1	"	metre.
Hectolitre	=	100	"	=	100	"	decimetres.
Decalitre	=	10	"	=	10	"	decimetres.
LITRE	=	1	"	=	1	"	decimetre = $\begin{cases} 3{\cdot}937^3 = \\ 61{\cdot}027 \text{ cu. in.} \end{cases}$
Decilitre	=	0·1	"	=	100	"	centimetres.
Centilitre	=	0·01	"	=	10	"	centimetres.
Millilitre	=	0·001	"	=	1	"	centimetre.

The *myrialitre*, or *kilolitre*, is hardly ever used.

The *hectolitre* is the ordinary unit for cereals, potatoes, and other dry products ; alcohol, wine, and oil, are also sold by the hectolitre.

The *decalitre* is very commonly used, also the *double decalitre.* The *litre* and *double litre* are employed for liquids, as well as for some kinds of vegetables. The litre answers to both the gallon and bushel.

The *decilitre* and *centilitre* are used for small quantities, and the *millilitre* (1 cubic centimetre) for delicate operations.

These measures are made of tin, brass, or wood, according to the use for which they are intended.

Those of tin and brass have generally a height double their diameter, those of wood have equal height and diameter. Such details are regulated by law in each country.

The reduction of French to English measures may be rather complicated, since it has to be inquired whether the wine, beer, dry, or imperial gallon is the one referred to. These are respectively equal to 231, 282, 268·8, and 277·274 cubic inches. The same difficulty applies to the bushel.

THE UNIT OF WEIGHT.

The unit of weight is the *gramme* (from the Greek *γραμμα*, a scruple), which *is the weight of* 1 *cubic centimetre of distilled water.*

The metre once agreed upon, the only difficult unit remaining to be established was that of weight: its volume was easy; but, since the authors of the Metric System were compelled to resort to water, the utmost care, by the laws of physics, was required to determine the weight of a given volume.

1. The water is distilled.

2. It is taken at its maximum degree of density, viz., 4° centigrade.

3. At the latitude of Paris, the altitude reduced to that of the sea-level and weighed in vacuum.

One gramme = 15·43234874 grains.

The following table is self-explanatory:

		Grammes.						
Myriagramme	=	10,000	=	10	cu. decimetres of water	=	22·0462125	lbs. avoir.
Kilogramme	=	1,000	=	1	"	=	2·20462125	"
Hectogramme	=	100	=	100	cu. centimetres of water	=	3·527	oz. avoir.
Decagramme	=	10	=	10	"	=	154·323	grammes.
GRAMME	=	1	=	1	"	=	15·43234874	"
Decigramme	=	0·1	=	100	cu. millimetres of water.	=	1·543...	"
Centigramme	=	0·01	=	10	"	=	0·154...	"
Milligramme	=	0·001	=	1	"	=	0·015...	"

A mere glance at this table shows that 1 kilogramme is equal to 1,000 cubic centimetres, or to 1 cubic decimetre. Consequently, 1 cubic metre or 1,000 cubic decimetres weighs 1,000 kilogrammes or 1,000,000 grammes; or, again, 1,000,000,000 milligrammes, as shown by the table on page 20, where cubic millimetres must be replaced by *milligrammes*, cubic centimetres by *grammes*, and cubic decimetres by *kilogrammes.*

Hence an easy method to solve such a question:

How many myriagrammes, kilogrammes, hectogrammes, decagrammes, grammes, decigrammes, centigrammes, and milligrammes, are there in a cubic metre filled with distilled water?

A cubic metre = 1,000,000 cubic centimetres, and a myriagramme = 10,000 grammes, hence 1 cubic metre contains—

$$\frac{1,000,000}{10,000} = \ldots \text{ 100 myriagrammes.}$$

So also—

$$\frac{1,000,000}{1,000} = \ldots \text{ 1,000 kilogrammes.}$$

$$\frac{1,000,000}{100} = \ldots \text{ 10,000 hectogrammes.}$$

$$\frac{1,000,000}{10} = . \text{ 100,000 decagrammes.}$$

$$\frac{1,000,000}{1} = . \text{ 1,000,000 grammes.}$$

$$\frac{1,000,000,000}{100} = \text{ 10,000,000 decigrammes.}$$

$$\frac{1{,}000{,}000{,}000}{10} = 100{,}000{,}000 \text{ centigrammes.}$$

$$\frac{1{,}000{,}000{,}000}{1} = 1{,}000{,}000{,}000 \text{ milligrammes.}$$

The gramme is so small a weight that larger units are necessary; the kilogramme is the most general. For shipping, freight, etc., *the Ton, or* 1,000 *kilogrammes, which is the weight of* 1 *cubic metre of distilled water*, is the unit. There is also the *Metric Quintal* (tenth part of a ton, or 100 kilogrammes). Flour is sold by the quintal.

The *myriagramme* is generally replaced by its equivalent, 10 kilogrammes.

The *kilogramme* is the weight commonly used, and is really the popular unit. One generally calls for 2½ kilos of sugar, *kilo* being an abbreviation of kilogramme, and the *half-kilogramme* is preferred to its equivalent 500 grammes.

Hectogramme and *decagramme* are much in use, though it is more habitual to say 100 and 10 grammes.

The submultiples are employed when delicate measurements are required; then we hear also of $\frac{1}{10}$, $\frac{1}{100}$, $\frac{1}{1000}$, ... of a milligramme.

The expression *half a gramme* is preferred to that of 5 decigrammes.

The weights of commerce are generally made of iron or brass; the submultiples are similar to those employed by apothecaries in this country. Their construction, as that of the litre, is generally determined by law.

The reduction of French to English measures is simple, when it is known that a troy pound is 5,760 grains, and an avoirdupois pound 7,000 grains.

THE UNIT OF MONEY.

In spite of numberless monetary congresses, no unit has been adopted, and none yet proposed that can be expected to become universal. The difficulties are more imaginary than real; but, on account of a so-called patriotism, the adoption of a system is offered to other nations, with the tacit understanding, however, that no change shall be made in the system of the proposing nation. No wonder that such congresses fail.

For the nations forming the "Latin Union"—an international convention which must last until 1880—and who have adopted two standards, one of gold and another of silver, the problem cannot be solved, for these two commercial products have a constantly varying value, and silver must be discarded as a standard.

The following table gives the French moneys:

	Value of the coins in francs.	Weight in grammes.	Diameter in millimetres.
Gold...........	100	32·25806	35
	50	16·12903	28
	20	6·45161	21
	10	3·2258	19
	5	1·6129	17
Silver.........	5	25	37
	2	10	27
	1	5	23
	½ = 50 centimes	2·5	18
	⅕ = 20 "	1	15

	Value of the coins in francs.	Weight in grammes.	Diameter in millimetres.
Bronze........	$\frac{1}{10}$ = 10 centimes	10	30
	$\frac{1}{20}$ = 5 “	5	25
	$\frac{1}{50}$ = 2 “	2	20
	$\frac{1}{100}$ = 1 “	1	15

The franc has no multiples according to the notation of the Metric System; that is, there is no *decafranc* nor *hectofranc*, but its submultiples are the *decime* (instead of *decifranc*), which is employed in taxation, and the *centime* (instead of *centifranc*).

Bronze coins are mere tokens, having a real value much below that marked on their faces.

Gold and silver coins are composed of 9 parts of pure metal and 1 of copper. Bronze coins are an alloy of 95 parts of copper, 4 of tin, and 1 of zinc.

The legal value of coined gold is 15½ times that of silver, and the value of this latter 20 times that of bronze. Consequently, a given weight of gold is worth ($15\frac{1}{2} \times 20 =$) 310 times its equivalent in bronze. Let us remark once more that these values are legal, and give trouble to the French Government, as in the money market gold is dearer than silver. Hence, the fineness of the silver coins below the denomination of the 5-franc piece being sometimes modified, the coin just referred to is the only legal tender, and the other silver and bronze coins are only taken to make up small balances.

A glance at the table shows that bronze and silver coins have weights easily memorized, and on this account very convenient; for instance, a weight of 15 grammes (about $\frac{1}{2}$ ounce) may be made with three pieces of 5 centimes in bronze, or one of 10 and one of 5, or with 2 and 1-centime pieces; also, in silver, with one piece of 2 francs and one of 1, or three of 1 franc, or six of 50 centimes, etc. Besides, 1 franc weighing 5 grammes 1,000 weigh 5,000 grammes, or 5 kilogrammes in silver, and $\left(\frac{5{,}000}{15{\cdot}5} =\right)$ 322·58 grammes in gold. Hence the value of a given weight of coined gold, silver, or bronze, is immediately known, and conversely. The diameter of the bronze coins proves available for measuring lengths.

In this country a like simplicity has been sought; a 5-cent nickel piece weighs 5 grammes, and its diameter is 20 millimetres.

We may here observe that the weights and diameters of coins, in order to be of practical utility, should be stamped thereon.

By an act of March 3, 1873, it is provided that the Secretary of the Treasury shall determine the values of foreign coins on the first day of January of every year, and accordingly the value for 1876 of

One franc = 19·3 cents.

When nations are willing to agree on a universal coinage, they will all have to change their monetary system. The French may keep the franc as a name and make it 20 cents, and the English their pound and make it 5 dollars, so that 1 *pound sterling* = 5 *dollars* = 25 *francs*. But the dollar, pound, and franc, will have to be altered from their present value. Supposing nations to be wise enough to yield thus much, two other very important elements remain to be determined—fineness and weight—in such a manner that a given weight shall represent a given amount, and for this gold does not readily answer. For 1 gramme of French-coined gold is worth $\left(\frac{5}{1{\cdot}6129} =\right)$ 3·10 francs, or almost 60 cents.[1]

As to the monetary unit, the altered dollar seems to answer best (it matters little whether it be called peso, duro, florin, or thaler), for the franc is too small and the pound sterling too large; besides, many nations have coins approximating that value.

At the present time momentous financial problems agitate the American Republic, and, on the eve of returning to specie payments, it would be of the utmost importance to study the question. The present juncture is the most favorable that can be found, but it is useless to expect the coöperation of other nations in such a reform. The United States Government has shown more good-will than any other, at times studying the propriety of reducing the dollar to the value of the 5-franc piece, at others of making it an exact fifth of the English pound. The fineness of 9 parts of pure metal to 1 of copper is preferable on account of the simplicity of these proportions, and in this case a coin weighing 5 grammes would offer many advantages, its value being 3 actual dollars within less than one cent; but then its submultiples, to be decimal, would greatly differ in value from the present ones. It is important to notice that, in the expectation of a reform, Japan, in 1870, and the Argentine Republic more recently, led the way in adopting the *yen* and the *peso fuerte*, each weighing 1½ gramme of gold in the above conditions.

---

[1] The advantage of a given weight for a monetary unit is obvious, and in conformity with the usage of antiquity. Even now the English pound sterling derives its origin from one pound-weight of copper coins, and the Spanish-Americans have a marked preference for gold ounces. A gold gramme would be too small a coin, but the unit might be 2 grammes ($1·1965), or 5 grammes (15·50 francs = $2·99).

CONCLUDING OBSERVATIONS.

The simplicity of the Metric System is striking (its calculations being so easy as to be performed mentally), and its use cannot fail soon to become universal. Once known it cannot be forgotten, and this much cannot be said of any other system. In the English tables, for instance, not even one of the simplest (that of the measures of length) can be long remembered.

The Greek names may seem awkward, and some nations may change them, as in France even many multiples and submultiples are obsolete; but the system is decimal, and will always remain so. In the foregoing pages we have explained the system as in actual use in France, and the problems which we now give will make it perfectly clear.

Let us add that this system does not and cannot cover all our requirements—the circumference of the circle has been advantageously adapted to it, but this division has not prevailed; the calendar is not perfect, nor is the division of the day. Physics also constantly require new units for heat, electricity, hygrometry, etc.

The following table will be found useful for reference :

1 yard	=	0·91438347	metre.
1 foot	=	0·30479449	“
1 inch	=	0·02539954	“
1 mile	=	1·6093149072	kilometre.
1 square foot	=	0·093040	square metre.
1 acre	=	40·46711	ares.
1 square mile	=	2·59405	sq. kilometres.
1 cubic foot	=	28·318019	cubic decimetres.
1 grain	=	0·06479895	gramme.
1 pound avoir.	=	0·4535926525	kilogramme.
1 ton (2,240 lbs.)	=	1·0160475416	metric ton.
1 gallon (imp'al)	=	4·54368	litres.
1 metre	=	1·09363307	yard.
		3·2808992	feet.
		39·3707904	inches.
1 kilometre	=	0·621383	mile (5,280 feet).
1 square metre	=	10·74702	square feet.
1 are	=	0·0247114	acre.
1 sq. kilometre	=	0·385496	square mile.
1 cubic metre	=	35·31481	cubic feet.
1 gramme	=	15·43234874	grains.
1 kilogramme	=	2·20462125	pounds avoir.
1 litre	=	0·220096	gallon (imperial).
		61·027053	cubic inches.

PROBLEMS.

ALL the problems relating to the reduction of French to English measures, and conversely, must be performed with the following data, the number of decimals taken depending upon the degree of accuracy required:

1 metre = 39·3707904 inches.
1 gramme = 15·43234874 grains.

1. How many centimetres are there in a metre? Of millimetres in a decametre? Of decimetres in a hectometre? Of centimetres in a myriametre?

2. How many metres, hectometres, kilometres, and myriametres, are there in the meridian of the earth?

3. How many metres are there in 8 myriametres; 15 kilometres; 327 hectometres; 25 decametres; 250 decimetres; 250 millimetres; and 250 ten-millimetres (1 ten-millimetre = $\frac{1}{10}$ of 1 millimetre)?

4. Write, with the kilometre as unit: 35·05 myriametres; 325.4 hectometres; and 325·35 metres.

5. Write, with the metre as unit: $\frac{3}{1,000,000}$ of a millimetre.

6. If a metre of silk be worth $3·75, what is the price of 48 centimetres?

7. If a train travel at a speed of 50 kilometres per hour during 24 hours, how many myriametres will have been traveled over?

8. What are the $\frac{4}{9}$ of 17·28 metres? Of 17·28 kilometres?

9. How many steps, of 24 centimetres, are there in a tower 86·4 metres high?

10. What decimal fraction of the metre, to 4 places, are the yard, the foot, the inch?

Suggestion: $\frac{36}{39{\cdot}3708}$; $\frac{12}{39{\cdot}3708}$; $\frac{1}{39{\cdot}3708}$.

11. Express the value of the metre, to 4 places of decimals, in yard and feet.

12. Convert 3·325 kilometres into miles; also 2 miles, 2 furlongs, 2 poles, 2 yards, 2 feet, and 2 inches, into kilometres.

13. A fathom being 6 feet, to what depth in metres correspond 15 fathoms?

14. Express in kilometre, to 4 places of decimals, the value of the mile, and conversely, the value of the kilometre in mile.

15. A sewing-machine sews in 1 minute 225 stitches of 4 millimetres each; how much time would it take a seamstress, sewing 4 metres in an hour, to accomplish the same work as the machine performs in 12 hours and 40 minutes? *Ans.* 171 hours.

16. How many square decimetres are there in 1 square metre, 1 are, 1 hectare?

17. How many square millimetres are there in 1

square metre; 1 square decimetre; 1 square centimetre; 1 square decametre; 1 square hectometre; and 1 myriare?

18. How many square metres and ares are there in 155·5 square decametres?

19. How many square millimetres are there in the $\frac{2}{5}$ of 20 square metres?

20. Write and add 5 square centimetres; 5 square millimetres; 5 square decimetres; 115 square millimetres; 115 square decimetres; 115 square centimetres; 1,004 square millimetres; 303 square centimetres; 1,020 square millimetres; and 320 square decimetres.

Ans. 4·444444 square metres.

21. A board whose area is 5·60 square metres has cost $1·60; determine the value of the square metre.

22. Divide 484·0408 square metres into 16 equal parts.

23. The length of a hall is 12·5 metres and its area 31·25 square metres; determine: first, its width; and second, how many square tiles, whose sides are 0·25 metre, are required to cover it.

Ans. First, 2·50 metres; second, 500.

24. How many funnels can be made with 26 square metres of tin, if each funnel needs 13 square decimetres of material?

25. What are the $\frac{2}{7}$ of 42 square decimetres?

26. What is the $\frac{1}{8}$ of $484\frac{1}{2}$ hectares?

Ans. 60 hectares, 56 ares, 25 centiares.

27. From a piece of pasteboard of 24 square decimetres, how many squares 0·04 metre long can be cut?

28. Determine the value of the hectare in square feet, square yards, square poles, square roods, and acres.

29. Determine the value of the square kilometre in square mile, and conversely.

First Solution.

The square kilometre $= 39{,}370{\cdot}8^2 = 1{,}547{,}571{,}610$ square inches.

The square mile $= (12 \times 3 \times 5\frac{1}{2} \times 40 \times 8)^2 = 63{,}360^2$ $= 4{,}014{,}489{,}600$ square inches.

Consequently—

$$\text{The sq. kilometre} = \frac{1{,}547{,}571{,}610}{4{,}014{,}489{,}600} = 0{\cdot}38 \text{ of a sq. mile.}$$

$$\text{The sq. mile} = \frac{4{,}014{,}489{,}600}{1{,}547{,}571{,}610} = 2{\cdot}59 \text{ of a sq. kilometre.}$$

Second Solution.

Logarithm $39{,}370{\cdot}8^2 = 2 \times 4{\cdot}595175 = 9{\cdot}190346$

" $63{,}360^2 = 2 \times 4{\cdot}802500 = \underline{9{\cdot}605000}$

Difference, $\bar{1}{\cdot}585346$,

which logarithm corresponds to the number 0·3849.

Logarithm $63{,}360^2 = 9{\cdot}605000$

" $39{,}370{\cdot}8^2 = \underline{9{\cdot}190346}$

Difference, 0·414654, which is the logarithm of the number 2·598 +.

30. A meadow of 28 hectares 50 ares is divided among three farmers ; the part of the first is to that of the second as 11 is to 6, and the third must have

3 hectares more than the other two together. Which is the part of each one?

31. If 70 centiares of land be worth $56, what must be paid for 3 hectares 4 ares and 4 centiares?

32. How many cubic decimetres, centimetres, and millimetres, are there in 1 cubic metre and in 1 cubic decametre?

33. Read the following: 0·03 cubic metre; 5·5555 cubic metres; 6·2701 cubic metres; 0·02 cubic decimetre; 3·0333 cubic decimetres; 0·4 cubic centimetres.

34. How many cubic decimetres are there in the $\frac{3}{10}$ of 1 cubic metre? In 3 decisteres?

35. Write and add: 3 cubic metres and 30 cubic centimetres; 5 cubic decimetres and 5 cubic millimetres; 3,050 cubic millimetres; 0·12 cubic decimetre; 0·5 cubic centimetre; 0·3 cubic decimetre; 0·2 cubic metre; 20,102 cubic centimetres; and 2,330 cubic decimetres. *Ans.* 5·555555555 cubic metres.

36. How many cubic decimetres are there in half a stere, half a decistere, and half a decastere?

37. How many small boxes of a volume of 32 cubic centimetres can be packed in a box whose volume is 1·6 cubic metre?

38. How many cubic decimetres and cubic centimetres are there in 12 steres 2 decisteres?

39. What height will $2\frac{1}{2}$ decasteres of logs, 1·25 metre long, attain, if stored in a space 5 metres wide?

Solution.—$2\frac{1}{2}$ decasteres = 25 cubic metres = 5 × 1·25 × height. *Ans.* 4 metres.

40. How many cubic millimetres are there in the $\frac{3}{7}$ of 4·2 cubic metres?

41. Determine the value of the cubic metre in cubic feet and cubic yard.

First Solution.

$$\frac{39{\cdot}37^3}{12^3} = \frac{6{,}1{,}027}{1{,}728} = \begin{cases} \text{35 cubic feet 544 cubic inches, or} \\ \quad \text{35·314 cubic feet.} \end{cases}$$

$$\frac{39{\cdot}37^3}{(12 \times 3)^3} = 1{\cdot}3 \text{ cubic yard.}$$

Second Solution.

$$\begin{array}{lllll} \text{Logarithm} & 39{\cdot}37^3 & = 3 \times 1{\cdot}595165 & = & 5{\cdot}785495 \\ \quad\text{“} & 12^3 & = 3 \times 1{\cdot}079181 & = & \underline{3{\cdot}237543} \\ & & & \text{Difference,} & 2{\cdot}547952, \end{array}$$

which logarithm corresponds to the number 35·314

$$\begin{array}{lllll} \text{Logarithm} & 39{\cdot}37^3 & = & & 5{\cdot}785495 \\ \quad\text{“} & 36^3 & = 3 \times 1{\cdot}556303 & = & \underline{4{\cdot}668909} \\ & & & \text{Difference,} & 1{\cdot}116586, \end{array}$$

which logarithm corresponds to the number 1·308 +.

42. How many cubic centimetres are there in 1 litre? What is the equivalent of the cubic centimetre in a litre?

43. What fraction of a cubic metre is 1 decilitre, 1 hectolitre, 1 decalitre, 1 double hectolitre, and $\frac{1}{2}$ hectolitre?

44. How many decalitres, litres, decilitres, centilitres, and millilitres, are there in 1 hectolitre?

45. How many decilitres and decalitres are there in 1 kilolitre and 1 myrialitre?

46. What fraction of 1 litre are 5 cubic centimetres, 50 cubic centimetres, and 500 cubic centimetres?

47. Write and add 3 litres 3 decilitres; 3 decalitres and 3 centilitres; 10 hectolitres and 35 centilitres. *Ans.* 1033·68 litres.

48. How many cubic centimetres are there in 12 decilitres, 12 centilitres, and 12 millilitres? *Ans.* 1332.

49. How many kilolitres and cubic decimetres are there in 5 hectolitres, 44 decalitres, 55 litres, 37 decilitres, 86 centilitres, and 440 millilitres?

Ans. 1 kilolitre, or 1,000 cubic decimetres.

50. At \$35·60 a hectolitre of brandy, what is the price of the litre? At 8 cents a litre of milk, what is the price of the hectolitre?

51. How many bottles of 6 decilitres of capacity are required to hold 86 litres and 40 centilitres of liquor? *Ans.* 144.

52. If 30 hectolitres of oil cost \$720, what is the price of 1 decilitre? *Ans.* $2\frac{2}{5}$ cents.

53. Determine the equivalent of the litre in cubic inches, also in imperial gallon.

First Solution.

$$\text{A litre} = 3{\cdot}937^3 = 61{\cdot}02705 \text{ cubic inches.}$$

$$\text{"} \quad = \frac{3{\cdot}937^3}{277{\cdot}274} = 0{\cdot}220096 \text{ imperial gallon.}$$

Second Solution.

$$\begin{array}{lll} \text{Logarithm} & 3{\cdot}937^3 = 3 \times 0{\cdot}595165 = & 1{\cdot}785495 \\ \text{“} & 277{\cdot}274 = & \underline{2{\cdot}442909} \\ & \text{Difference,} & \bar{1}{\cdot}342586, \end{array}$$

which logarithm corresponds to the number 0·220083.

54. Determine the equivalents of the imperial gallon in litres and cubic decimetres.

Suggestion: $\frac{277{\cdot}274}{3{\cdot}9373^3}$.

55. Determine the equivalent of the litre in pint.

Suggestion: $\dfrac{3{\cdot}937^3}{\dfrac{277{\cdot}274}{8}}$.

56. Determine the equivalent of a bushel in hectolitre.

Suggestion.—A bushel = 8 gallons. Hence,

$$\frac{277{\cdot}274 \times 8}{3{\cdot}937^3 \times 100}.$$

57. What is the equivalent of the kilogramme in grammes, decagrammes, hectogrammes, myriagrammes, decigrammes, centigrammes, and milligrammes?

58. What is the weight of 1 cubic decimetre, and of 1 cubic metre, of distilled water?

59. What is the weight of 1 litre, of 1 decalitre, of 1 hectolitre, of 1 kilolitre, of 1 myrialitre, of 1 decilitre, of 1 centilitre, and of 1 millilitre, of distilled water?

60. Determine the weight of the same quantities of alcohol and of sea-water, whose densities are respectively 0·747 and 1·025.

61. Write and add 3 kilogrammes 2 grammes; 3 hectogrammes 3 decigrammes; 3 decagrammes 3 centigrammes; 1 gramme 3 milligrammes.

62. Write and add 2 tons, 13 quintals, 13 kilogrammes, and 200 hectogrammes.

Ans. 3 tons, 3 quintals, and 33 kilogrammes.

63. Add 5 tons 4 kilogrammes; 5 quintals 23 decagrammes; 4 myriagrammes 2 hectogrammes; 11 kilogrammes 6 grammes; 1 hectogramme 44 centigrammes; 1 decagramme 1 decigramme; and 9 grammes 15 milligrammes.

Ans. 5 tons, 555 kilogrs., 555 grs., 555 mgrs.

64. Read 13·08 grammes; 15·030 kilogrammes; 15·35 myriagrammes; 0·005 gramme.

65. What is the weight of 1 stere of beech-wood whose density is 0·852, supposing that the empty spaces existing between the logs amount to $\frac{1}{6}$ of the bulk?

Ans. 710 kilogrammes.

66. If milk yields 15% of cream, and cream 21% of butter, how many hectolitres of milk are required to make 540 kilogrammes of butter, knowing that a litre of milk weighs 1,030 grammes?

Ans. 166 hectolitres 43·5 + litres.

67. What is the volume of 1251·77 grammes of gold whose density is 19·258?

Ans. 65 cubic centimetres.

68. What is the weight of a beam of iron 7 metres long, 25 centimetres thick, and 55 millimetres wide? The density of iron is 7·788.

Ans. 5 tons, 354 kilogrammes, 250 grammes.

69. What is the volume of 1 kilogramme of mercury, whose density is 13·596?

Ans. 73 cubic centim., 551 cubic millimetres.

70. Determine the equivalent of the pound avoirdupois in kilogramme, and conversely.

Suggestion: $\frac{7,000}{15{\cdot}432 \times 1,000}$; $\frac{15{\cdot}432 \times 1,000}{7,000}$.

71. The water in a steam-boiler weighs $9\frac{3}{4}$ metric tons, what volume does it occupy? Also, when filled with sea-water, whose density is 1·025?

Ans. Sea-water occupies 9·512 cubic metres.

72. Find in the above problem the weight and volume of this water (fresh) in equivalent pounds, cubic feet, and imperial gallons.

Ans. 21,450 lbs.; 344 cubic feet 552 cubic inches; 2,145 gallons.

73. How can a weight of 15 grammes be made in French and United States coins?

Ans. With 3 francs in silver, or 15 centimes in bronze; with 3 five-cent nickel pieces.

74. What is, first, the value of 1 kilogramme of French-coined silver; second, of French-coined gold; third, how many 5-franc silver pieces are required to make up that weight?

Solution.—1. $\frac{1,000}{5} = 200$ francs.

2. $\frac{1,000 \times 15{\cdot}5}{5} = 3,100$ francs.

3. $\frac{1,000}{25} = 40$ silver pieces of 5 francs.

75. What would be the weight, first, of 5 milliards of francs in gold (a milliard being 1,000 millions), the indemnity paid by France at the end of the Franco-German War; second, of 1 milliard 800 millions of francs, the largest sum of gold ever collected, and which lay in the vaults of the Bank of France in March, 1876?

Suggestion.

In silver the weight would be $5{,}000{,}000{,}000 \times 5$ grammes, and in gold $15\frac{1}{2}$ times less; $\frac{5{,}000{,}000{,}000 \times 5}{15{\cdot}5}$ = 1,612 tons, 903 kilogrammes, 226 grammes.

76. Make 1 decimetre with French and United States coins.

Ans. With 5 pieces of 2 centimes; or 4 of 5; or 2 of 10 and 2 of 2, etc.; with five-cent nickel pieces.

77. The United States postal treaty, with countries using the Metric System, recognizes 15 grammes as equivalent to $\frac{1}{2}$ ounce avoirdupois; who benefits by it and by what percentage?

Ans. The Metric System gains 12·73 grains, or 5·8 per centum.

ADDITIONAL PROBLEMS.

78. Determine the diameter of the earth in kilometres and in miles.

Ans. 12,732 kilometres 395·4 m. = 7,911·7 miles.

REMARK.—In all problems relating to the earth we suppose it a perfect sphere; the diameter here given is almost an average between the polar axis, 12,712·227, and equatorial diameters, 12,754·937 kilometres. Data given by Captain A. R. Clarke, and admitted as the most trustworthy.

79. The nautical mile, or knot, being one minute of a terrestrial degree, determine its value in metres and feet.

Solution.

$$\frac{10{,}000{,}000}{90 \times 60} = 1{,}851{\cdot}85 \text{ metres.}$$

$$1{,}851{\cdot}85 \times \frac{39{\cdot}37}{12} = 6{,}075{\cdot}06 \text{ feet.}$$

REMARK.—The result is approximative, for the nautical mile is a minute of a degree at the equator, or 1,855 m. = 6,086·5 feet.

80. Had the metric division of the circumference been generalized, the quadrant would contain 100 grades, each divided into 100 minutes, and these latter into 100 seconds. Determine the equivalents of the metre, and succeeding denominations, from the terrestrial meridian.

Solution.

$$100 \text{ grades} = 10{,}000' = 1{,}000{,}000''.$$

$$1 \text{ metre} = \frac{1}{10{,}000{,}000} \text{ of a quadrant} =$$

$$\frac{1{,}000{,}000}{10{,}000{,}000} = \tfrac{1}{10} \text{ of a second.}$$

Hence, 1 decametre = 1 second.
1 hectometre = 10 seconds.
1 kilometre = 100″, or 1 minute.
1 myriametre = 10 minutes.

81. Determine the velocity of rotation per minute

of a given point of the earth, on the equator, on the 45th and on the 60th parallels.

Solution.

At the equator $\frac{40{,}000{,}000}{24 \times 60} = 27{\cdot}777\ldots$ kilometres.

Radius of the 45th parallel $= \frac{1}{\sqrt{2}} = \frac{1{\cdot}41}{2} = 0{\cdot}707$ of the earth radius; hence, velocity $= 0{\cdot}707 \times 27{\cdot}7\ldots = 19{\cdot}638\ldots$ kilometres.

Radius of the 60th parallel $= \frac{1}{2}$ of the earth's radius; hence, velocity $= \frac{1}{2} \times 27{\cdot}77\ldots = 13{\cdot}888\ldots$ kilometres.

82. Determine the value in kilometres of the degree at the equator on the 30th, 45th, and 60th parallels.

83. Determine the area of the earth in millions of square kilometres, and of square miles.

Suggestion.

By problem 78 the diameter of the earth is 12,732·395 kilometres, its area or 4 great circles $= 40{,}000 \times \frac{12{,}732}{4} \times 4 = 509{,}295{,}816$ square kilometres, or about 510 millions of square kilometres, which correspond (Prob. 29) to about 193·8 millions of square miles.

84. Determine the volume of the earth in millions of cubic kilometres and of cubic miles.

Suggestion.

The preceding problem gives the area of the earth, and 78 its diameter, hence its volume is—

$$509{,}295{,}816 \times \frac{12{,}732}{6} = 1{,}080{,}000 \text{ millions}$$ ~~of millions~~ of cubic kilometres.

Taking the data in miles, found in the same problems, we find for the volume of the earth 255,000 millions of cubic miles. The same approximation may be derived as follows :

1 cubic metre = 35·314 cubic feet (Prob. 41).

1 cubic kilometre = 35·314 × 1,000,000,000 = 35,314,000,000,000 cubic feet.

1,080,000,000,000,000 cubic kilometres = 38,139,120,000,000,000,000,000,000,000 cubic feet. (1.)

Now, 1 cubic mile = $(3 \times 5\frac{1}{2} \times 40 \times 8)^3 = 5{,}280^3$ cubic feet.

1 million of cubic miles = $5{,}280^3 \times 1{,}000{,}000$ cubic feet. (2.)

Dividing result 1 by 2, by logarithms—

$$\left.\text{Log. } 38{,}139{,}120{,}000{,}000{,}000{,}000{,}000{,}000{,}000\right\} = 28{\cdot}581369$$

$$\left.\begin{array}{ll}\text{“} & 5{,}280^3 = 3 \times 3{\cdot}722634 = 11{\cdot}167902 \\ \text{“} & 1{,}000{,}000 = \qquad\qquad 6{\cdot}000000\end{array}\right\} = 17{\cdot}167902$$

Difference, 11·413467,

which is the logarithm of the number 259,100,000,000, or about 259,000 millions of cubic miles.

85. The litre used for measuring liquids is a cylinder whose height is double its diameter. Determine these dimensions.

Ans. Diameter = 0·086 ; height = 0·172.

86. Assuming the altitude of the Peak of Teneriffe

to be 12,182 feet, first, from how many kilometres is it theoretically visible at the sea-level, supposing the tangent from the summit sufficiently accurate; second, what is the length of the arc of great circle projection of this tangent?

Solution.—12,182 feet = 3,712·6 metres.

1. Tangent $= \sqrt{(12{,}732{\cdot}39 + 3{\cdot}71)\, 3{\cdot}71} = 217{\cdot}4$ kilom.

2. But angle $= \dfrac{\text{tangent}}{\text{radius}} = 1^\circ\, 57'\, 21''$.

$$\therefore \text{ Arc} = \frac{10{,}000 \times 1^\circ\, 57'\, 21''}{90} = 217{\cdot}3 \text{ kilometres.}$$

87. The pressure of the atmosphere, with the barometer standing at 29·92 inches of mercury, is 14·7 pounds on the square inch. Determine the equivalents in the Metric System.

Solution.

$$29{\cdot}92 \text{ inches} = \frac{29{\cdot}92}{39{\cdot}37} = 0.759 \text{ metre.}$$

1 centimetre = 0·3937 and 1 square centimetre = 0·155 square inch. Representing the pressure on the square centimetre by x—

$$1 : 0{\cdot}155 :: 14{\cdot}7 : x = 2{\cdot}28 \text{ pounds.}$$

Now, 1 pound weighs 7,000 grains, and 2·28 lbs. weigh

$$7{,}000 \times 2{\cdot}28 \text{ grains} = \frac{7{,}000 \times 2{\cdot}28}{15{\cdot}43} = 1{,}034 \text{ grammes.}$$

Remark.—In French works the atmospheric pressure is reckoned at 1·033 kilogramme on the square centimetre, the barometer standing at 0·76 metre, and the data of this problem allow the conversion of a certain number of atmospheres (the unit of pressure on steam-gauges) into their equivalents in pounds, also a certain number of inches on the vacuum-gauge in fraction of the atmospheric pressure.

88. One horse-power being 33,000 pounds raised 1 foot high in 1 minute, to how many kilogrammes raised 1 metre high in 1 second does it correspond?

Solution.

$$\frac{33{,}000}{60} = 550 \text{ pounds raised 1 foot in 1 second.}$$

$$1 \text{ pound} = \frac{7{,}000}{15{\cdot}432} \text{ grammes} = \frac{7{,}000}{15{,}432} \text{ kilogrammes.}$$

$$550 \quad \text{“} \quad = \frac{7{\cdot}000}{15{\cdot}432} \times 550.$$

$$1 \text{ foot} = \frac{12}{39{\cdot}37} \text{ metre.}$$

Hence, 550 pounds raised 1 foot $= \dfrac{7{,}000}{15{,}432} \times 550 \times \dfrac{12}{39{\cdot}37} = 0{\cdot}453 \times 550 \times 0{\cdot}304 = 75{\cdot}73$ kilogrammes raised 1 metre high in 1 second.

REMARK.—1 *pound* raised 1 *foot* high is called 1 *foot-pound.*
1 *kilogramme* “ 1 *metre* “ 1 *kilogrammetre.*

The horse-power is reckoned in French works at 75 kilogrammetres for the sake of simplicity. A kilogrammetre is equal to—

$$\frac{15{,}432}{7{,}000} \times \frac{39{\cdot}37}{12} = 2{\cdot}2 \times 3{\cdot}28 = 7{\cdot}233 \text{ foot-pounds.}$$

89. The mechanical equivalent of heat, according to Joule, is 772 foot-pounds: determine its equivalent in the Metric System.

Solution.

Let us remark that 772 foot-pounds represent the energy required for raising 1 pound of water 1 degree of the Fahrenheit thermometer scale; had it been necessary to raise 1 pound of water 1 degree centigrade, it would need—

$$772 \times \frac{(212 - 32)}{100} = 772 \times \tfrac{9}{5} = 1{,}389{\cdot}6 \text{ foot-pounds.}$$

1 kilogramme of water is raised 1 degree centigrade by

$$1{,}389{\cdot}6 \times \frac{15{,}432}{7{,}000} \text{ foot-pounds, which contains}$$

$$\frac{1{,}389{\cdot}6 \times \dfrac{\cancel{15{,}432}}{\cancel{7{,}000}}}{\dfrac{\cancel{15{,}432}}{\cancel{7{,}000}} \times \dfrac{39{\cdot}37}{12}} = \frac{1{,}389{\cdot}6}{3{\cdot}28} = 423{\cdot}5 \text{ kilogrammetres.}$$

REMARK.—French authors, for the sake of simplicity, make the mechanical equivalent of heat 425 kilogrammetres.

90. Determine the equivalents in English measures of the metre and of the gramme.

The metre being a distance taken on the globe itself, it was necessary to estimate in English measures a terrestrial arc; consequently, assuming 6,076·5 feet for the mean length of a minute, the metre ought to be 39·37572 inches.

But the meridian, as remarked on page 8, cannot be exactly measured, consequently a definitive equivalent upon such a basis is impossible to be determined. The one chosen in this work is that legalized in England and in the United States.

Accepting that a cubic inch of distilled water weighed in air at a temperature of 62° Fahrenheit, with the barometer at 30 inches, weighs 252·438 grains, we must at first find its weight at 4° centigrade. Making use of Kopp's table, where the maximum density of water is given at 39·2° Fahrenheit, and 62·6° is the nearest point to 62°, the volumes of water are respectively 0·999877 and 1·001010.

$$\therefore\ 1{\cdot}001010 : 0{\cdot}999877 :: 252{\cdot}438 : x = 252{\cdot}27215.$$

The cubic inch equals 16·386 cubic centimetres, hence one cubic centimetre of water weighs—

$$\frac{252.27215}{16{\cdot}386} = 15{\cdot}38094 \text{ grains.}$$

But the gramme is that same volume weighed in vacuum, and supposing that a cubic decimetre of air at 0° centigrade, the barometer standing at 0·76 metre, weighs 1·293 gramme, then its density is $\frac{1{\cdot}293}{1{\cdot}000}$, which is also the weight of one cubic centimetre of air; consequently, in vacuum, one cubic centimetre weighs

$$15{\cdot}38094 + \frac{15{\cdot}38094 \times 1{\cdot}293}{1{,}000} = 15{\cdot}40083 \text{ grains.}$$

It is beyond our province to examine the incorrectness of these rough results, for each individual datum and each individual operation is open to criticism, and the discussion of the above problem is the history of the Metric System both in England and in the United States.

THE END.

INTERNATIONAL SCIENTIFIC SERIES.

NOW READY.

No. 1. **FORMS OF WATER,** in Clouds, Rain, Rivers, Ice, and Glaciers. By Prof. John Tyndall, LL. D., F. R. S. 1 vol. Cloth. Price, $1.50.

No. 2. **PHYSICS AND POLITICS;** or, Thoughts on the Application of the Principles of "Natural Selection" and "Inheritance" to Political Society. By Walter Bagehot, Esq., author of "The English Constitution." 1 vol. Cloth. Price, $1.50.

No. 3. **FOODS.** By Edward Smith, M. D., LL. B., F. R. S. 1 vol. Cloth. Price, $1.75.

No. 4. **MIND AND BODY.** The Theories of their Relation. By Alex. Bain, LL. D., Professor of Logic in the University of Aberdeen. 1 vol., 12mo. Cloth. Price, $1.50.

No. 5. **THE STUDY OF SOCIOLOGY.** By Herbert Sprncer. Price, $1.50.

No. 6. **THE NEW CHEMISTRY.** By Prof. Josiah P. Cooke, Jr., of Harvard University. 1 vol., 12mo. Cloth. Price, $2.00.

No. 7. **THE CONSERVATION OF ENERGY.** By Prof. Balfour Stewart, LL. D., F. R. S. 1 vol., 12mo. Cloth. Price, $1.50.

No. 8. **ANIMAL LOCOMOTION;** or, Walking, Swimming, and Flying, with a Dissertation on Aëronautics. By J. Bell Pettigrew, M. D., F. R. S., F. R. S. E., F. R. C. P. E. 1 vol., 12mo. Fully illustrated. Price, $1.75.

No. 9. **RESPONSIBILITY IN MENTAL DISEASE.** By Henry Maudslfy, M. D. 1 vol., 12mo. Cloth. Price, $1.50.

No. 10. **THE SCIENCE OF LAW.** By Prof. Sheldon Amos. 1 vol., 12mo. Cloth. Price, $1.75.

No. 11. **ANIMAL MECHANISM.** A Treatise on Terrestrial and Aërial Locomotion. By E. J. Marey. With 117 Illustrations. Price, $1.75.

No. 12. **THE HISTORY OF THE CONFLICT BETWEEN RELIGION AND SCIENCE.** By John Wm. Draper, M. D., LL. D., author of "The Intellectual Development of Europe." Price, $1.75.

No. 13. **THE DOCTRINE OF DESCENT AND DARWINISM.** By Prof. Oscar Schmidt, Strasburg University. Price, $1.50.

No. 14. **THE CHEMISTRY OF LIGHT AND PHOTOGRAPHY.** In its Application to Art, Science, and Industry. By Dr. Hermann Vogel. 100 Illustrations. Price, $2.00.

No. 15. **FUNGI;** their Nature, Influence, and Uses. By M C. Cooke, M. A., LL. D. Edited by Rev. M. J. Berkeley, M. A., F. L. S. With 109 Illustrations. Price, $1.50.

No. 16. **THE LIFE AND GROWTH OF LANGUAGE.** By Prof. W. D. Whitney, of Yale College. Price, $1.50.

No. 17. **MONEY AND THE MECHANISM OF EXCHANGE.** By W. Stanley Jevons, M. A., F. R. S., Professor of Logic and Political Economy in the Owens College, Manchester. Price, $1.75.

No. 18. **THE NATURE OF LIGHT,** with a General Account of Physical Optics. By Dr. Eugene Lommel, Professor of Physics in the University of Erlangen. With 188 Illustrations and a Plate of Spectra in Chromolithography. Price, $2.00.

No. 19. **ANIMAL PARASITES AND MESSMATES.** By Monsieur Van Beneden, Professor of the University of Louvain, Correspondent of the Institute of France. With 83 Illustrations. Price, $1.50.

No. 20. **ON FERMENTATIONS.** By P. Schützenberger, Director at the Chemical Laboratory at the Sorbonne. With 28 Illustrations. Price, $1.50.

No. 21. **THE FIVE SENSES OF MAN.**

D. APPLETON & CO., Publishers, 549 & 551 Broadway, N. Y.

THE INTERNATIONAL SCIENTIFIC SERIES.

D. Appleton & Co. have the pleasure of announcing that they have made arrangements for publishing, and have recently commenced the issue of, a Series of Popular Monographs, or small works, under the above title, which will embody the results of recent inquiry in the most interesting departments of advancing science.

The character and scope of this series will be best indicated by a reference to the names and subjects included in the subjoined list, from which it will be seen that the coöperation of the most distinguished professors in England, Germany, France, and the United States, has been secured, and negotiations are pending for contributions from other eminent scientific writers.

The works will be issued in New York, London, Paris, Leipsic, Milan, and St. Petersburg.

The International Scientific Series is entirely an American project, and was originated and organized by Dr. E. L. Youmans, who has spent much time in Europe, arranging with authors and publishers.

FORTHCOMING VOLUMES.

Prof. W. KINGDON CLIFFORD, M. A. *The First Principles of the Exact Sciences explained to the Non-mathematical.*

Prof. T. H. HUXLEY, LL. D., F. R. S. *Bodily Motion and Consciousness.*

Dr. W. B. CARPENTER, LL. D., F. R. S. *The Physical Geography of the Sea.*

Prof. WILLIAM ODLING, F. R. S. *The Old Chemistry viewed from the New Stand-point.*

W. LAUDER LINDSAY, M. D., F. R. S. E. *Mind in the Lower Animals.*

Sir JOHN LUBBOCK, Bart., F. R. S. *On Ants and Bees.*

Prof. W. T. THISELTON DYER, B. A., B. Sc. *Form and Habit in Flowering Plants.*

Mr. J. N. LOCKYER, F. R. S. *Spectrum Analysis.*

Prof. MICHAEL FOSTER, M. D. *Protoplasm and the Cell Theory.*

H. CHARLTON BASTIAN, M. D., F. R. S. *The Brain as an Organ of Mind.*

Prof. A. C. RAMSAY, LL. D., F. R. S. *Earth Sculpture: Hills, Valleys, Mountains, Plains, Rivers, Lakes; How they were Produced, and how they have been Destroyed.*

Prof. RUDOLPH VIRCHOW (Berlin University). *Morbid Physiological Action.*

Prof. CLAUDE BERNARD. *History of the Theories of Life.*

D. APPLETON & CO., Publishers, 549 & 551 Broadway, N. Y.

THE INTERNATIONAL SCIENTIFIC SERIES.

FORTHCOMING VOLUMES.

Prof. H. SAINTE-CLAIRE DEVILLE. *An Introduction to General Chemistry.*

Prof. WURTZ. *Atoms and the Atomic Theory.*

Prof. De QUATREFAGES. *The Human Race.*

Prof. LACAZE-DUTHIERS. *Zoölogy since Cuvier.*

Prof. BERTHELOT. *Chemical Synthesis.*

Prof. C. A. YOUNG, Ph. D. (of Dartmouth College). *The Sun.*

Prof. OGDEN N. ROOD (Columbia College, N. Y.). *Modern Chromatics and its Relations to Art and Industry.*

Prof. J. ROSENTHAL. *General Physiology of Muscles and Nerves.*

Prof. JAMES D. DANA, M. A., LL. D. *On Cephalization; or, Head-characters in the Gradation and Progress of Life.*

Prof. S. W. JOHNSON, M. A. *On the Nutrition of Plants.*

Prof. AUSTIN FLINT, Jr., M. D. *The Nervous System, and its Relation to the Bodily Functions.*

Prof. FERDINAND COHN (Breslau University). *Thallophytes (Algæ, Lichens, Fungi).*

Prof. HERMANN (University of Zurich). *Respiration.*

Prof. LEUCKART (University of Leipsic). *Outlines of Animal Organization.*

Prof. LIEBREICH (University of Berlin). *Outlines of Toxicology.*

Prof. KUNDT (University of Strasburg). *On Sound.*

Prof. REES (University of Erlangen). *On Parasitic Plants.*

Prof. STEINTHAL (University of Berlin). *Outlines of the Science of Language.*

P. BERT (Professor of Physiology, Paris). *Forms of Life and other Cosmical Conditions.*

E. ALGLAVE (Professor of Constitutional and Administrative Law at Douai, and of Political Economy at Lille). *The Primitive Elements of Political Constitutions.*

P. LORAIN (Professor of Medicine, Paris). *Modern Epidemics.*

Mons. FREIDEL. *The Functions of Organic Chemistry.*

Mons. DEBRAY. *Precious Metals.*

Prof. CORFIELD, M. A., M. D. (Oxon.). *Air in its Relation to Health.*

Prof. A. GIARD. *General Embryology.*

D. APPLETON & CO., PUBLISHERS, 549 & 551 Broadway, N. Y.

RECENT PUBLICATIONS.

Diseases of Modern Life. By Dr. B. W. Richardson, F. R. S. 1 vol., 12mo. Cloth. $2.00.

"'Diseases of Modern Life' is a work which throws so much light on what it is of the utmost importance for the public to know, that it deserves to be thoroughly and generally read."—*Graphic.*

'The literature on preventive medicine has received no more valuable contribution than this admirably-written treatise by one of the most accomplished physicians of Great Britain, who has concentrated upon his task a great amount of scientific research and clinical experience. No book that we have ever read more fully merits the attention of the intelligent public, to whom it is addressed."—*The World.*

Comin' Thro' the Rye. 1 vol., 8vo. Paper covers. 75 cents.

"A very amusing and well-written story. The history of the youth of the Adairs is extremely amusing, and told in a bright and witty manner. . . . One of the pleasantest novels of the season."—*Morning Post.*

"It is a clever novel, never dull, and the story never hangs fire."—*Standard.*

Memoir and Correspondence of Caroline Herschel. By Mrs. John Herschel. With Portraits. 12mo. Cloth. $1.75.

"The unlimited admiration excited by the noble, heroic virtues, and the uncommon talents of the subject of the memoir, is overborne by the intense sympathy felt for her long life of unselfish and unregretted devotion to others."—*Chicago Tribune.*

General History of Greece, from the Earliest Period to the Death of Alexander the Great. By the Rev. George W. Cox. 1 vol., 12mo. Cloth. $2.50.

"We envy those schoolboys and undergraduates who will make their first acquaintance with Greek history through Mr. Cox's admirable volume. It ought to supersede all the popular Histories of Greece which have gone before it."—*The Hour.*

"The book is worthy, in every way, of the author's reputation. . . . It is altogether a most interesting and valuable book."—*Educational Times.*

A Short History of Natural Science and of the Progress of Discovery from the Time of the Greeks to the Present Day. By Arabella B. Buckley. With Illustrations. 1 vol., 12mo. $2.00.

"Miss Buckley, the friend of Sir Charles Lyell, and for many years the secretary of the great geologist, in this volume has given a continuous, methodical, and complete sketch of the main discoveries of science from the time of Thales, one of the seven wise men, B. C. 700, down to the present day. The work is unique in its way, being the first attempt ever made to produce a brief and simple history of science. The author has entirely succeeded in her labors, evincing judgment, learning, and literary skill."—*Episcopal Register.*

A Hand-Book of Architectural Styles. Translated from the German by W. Cotlett-Sanders. 1 vol., 8vo. With 639 Illustrations. $6.00.

"There is a great amount of information in the book, in a small compass. For one who simply wishes to gain a full knowledge of the various styles of architecture, written in a clear and interesting manner, the volume has not its equal nor rival in the English language. This knowledge will be facilitated by the profuse illustrations, of which there are not less than six hundred and thirty-nine, nearly all handsome specimens of engraving, among which figure a large number of famous buildings, ancient and modern."—*Evening Mail.*

D. APPLETON & CO., 549 & 551 *Broadway, N. Y.*

Works of Charles Darwin.

JOURNAL OF RESEARCHES into the Natural History and Geology of the Countries visited during the Voyage of H. M. S. *Beagle* round the World, under the command of Captain Fitzroy, R. N. 1 vol., 12mo. 579 pages. Cloth. Price, $2.00.

"Darwin was nearly five years on board the *Beagle*. A keen observer, and a genuine philosopher, he has brought back to us a precious freight of facts and truths. The work has been for some time before the public, and has won a high place among readers of every class. It is not so scientific as to be above the comprehension of intelligent readers who are not scientific. Some facts and species, new even to the scientific, are brought to light. Darwin's transparent, eloquent style richly illuminates his observations. The weightier matters to which he alludes are interspersed among more familiar observations, such as would naturally be made by a traveler passing through new and wonderful scenes. It is an instructive and interesting book."—*Northwestern Christian Advocate.*

THE ORIGIN OF SPECIES by Means of Natural Selection, or the Preservation of Favored Races in the Struggle for Life. New and revised edition, with Additions. With copious Index. 1 vol., 12mo. Cloth. Price, $2.00.

"Personally and practically exercised in zoölogy, in minute anatomy, in geology, a student of geographical distribution, not in maps and in museums, but by long voyages and laborious collection; having largely advanced each of these branches of science, and having spent many years in gathering and sifting materials for his present work, the store of accurately-registered facts upon which the author of the 'Origin of Species' is able to draw at will, is prodigious."—*Prof. T. H. Huxley.*

THE DESCENT OF MAN, and Selection in Relation to Sex. With Illustrations. New edition, revised and augmented. Complete in one volume. 688 pages. Price, $3.00.

"This theory is now indorsed by many eminent scientists, who at first combated it, including Sir Charles Lyell, probably the most learned of geologists, and even by a class of Christian divines like Dr. McCosh, who think that certain theories of cosmogony, like the nebular hypothesis and the law of evolution, may be accepted without doing violence to faith."—*Evening Bulletin.*

THE EXPRESSION OF THE EMOTIONS IN MAN AND the Lower Animals. With Photographic and other Illustrations. 1 vol., thick 12mo. Cloth. Price, $3.50.

"Whatever one thinks of Mr. Darwin's theory, it must be admitted that his great powers of observation are as conspicuous as ever in this inquiry. During a space of more than thirty years, he has, with exemplary patience, been accumulating information from all available sources. The result of all this is undoubtedly the collection of a mass of minute and trustworthy information which must possess the highest value, whatever may be the conclusions ultimately deduced from it."—*London Times.*

INSECTIVOROUS PLANTS. With Illustrations. 1 vol., 12mo. Cloth. Price, $2.00.

"In conclusion, we lay this book down with increased admiration for Mr. Darwin as a discoverer and expositor of facts, and with great satisfaction at the increase to our knowledge of plant physiology given us, as well as the ample promise of further additions as the direct consequence of the present publication."—*London Athenæum.*

"In this work Mr. Darwin's patient and painstaking methods of investigation appear to the best possible advantage. It is impossible to read it without enthusiastic admiration for the ingenuity which he displays in devising tests to determine the characteristics of the plants, the peculiarities of which he is studying, and, as is always the case with him, he presents the conclusions arrived at in language so lucid that he who reads simply for information is sure to be attracted and charmed quite as much as the professional student."—*N. Y. Times.*

D. APPLETON & CO., PUBLISHERS, 549 & 551 Broadway, N. Y.

RECENT PUBLICATIONS.—SCIENTIFIC.

THE PRINCIPLES OF MENTAL PHYSIOLOGY. With their Applications to the Training and Discipline of the Mind, and the Study of its Morbid Conditions. By W. B. CARPENTER, F. R. S., etc. Illustrated. 12mo. 737 pages. Price, $3.00.

"The work is probably the ablest exposition of the subject which has been given to the world, and goes far to establish a new system of Mental Philosophy, upon a much broader and more substantial basis than it has heretofore stood."—*St. Louis Democrat.*

"Let us add that nothing we have said, or in any limited space could say, would give an adequate conception of the valuable and curious collection of facts bearing on morbid mental conditions, the learned physiological exposition, and the treasure-house of useful hints for mental training, which make this large and yet very amusing, as well as instructive book, an encyclopædia of well-classified and often very startling psychological experiences."—*London Spectator.*

THE EXPANSE OF HEAVEN. A Series of Essays on the Wonders of the Firmament. By R. A. PROCTOR, B. A.

"A very charming work; cannot fail to lift the reader's mind up 'through Nature's work to Nature's God.'"—*London Standard.*

"Prof. R. A. Proctor is one of the very few rhetorical scientists who have the art of making science popular without making it or themselves contemptible. It will be hard to find anywhere else so much skill in effective expression, combined with so much genuine astronomical learning, as is to be seen in his new volume."—*Christian Union.*

PHYSIOLOGY FOR PRACTICAL USE. By various Writers. Edited by JAMES HINTON. With 50 Illustrations. 1 vol., 12mo. Price, $2.25.

"This book is one of rare value, and will prove useful to a large class in the community. Its chief recommendation is in its applying the laws of the science of physiology to cases of the deranged or diseased operations of the organs or processes of the human system. It is as thoroughly practical as is a book of formulas of medicine, and the style in which the information is given is so entirely devoid of the mystification of technical or scientific terms that the most simple can easily comprehend it."—*Boston Gazette.*

"Of all the works upon health of a popular character which we have met with for some time, and we are glad to think that this most important branch of knowledge is becoming more enlarged every day, the work before us appears to be the simplest, the soundest, and the best."—*Chicago Inter-Ocean.*

THE GREAT ICE AGE, and its Relations to the Antiquity of Man. By JAMES GEIKIE, F. R. S. E. With Maps, Charts, and numerous Illustrations. 1 vol., thick 12mo. Price, $2.50.

"'The Great Ice Age' is a work of extraordinary interest and value. The subject is peculiarly attractive in the immensity of its scope, and exercises a fascination over the imagination so absorbing that it can scarcely find expression in words. It has all the charms of wonder-tales, and excites scientific and unscientific minds alike."—*Boston Gazette.*

"Every step in the process is traced with admirable perspicuity and fullness by Mr. Geikie."—*London Saturday Review.*

"'The Great Ice Age,' by James Geikie, is a book that unites the popular and abstruse elements of scientific research to a remarkable degree. The author recounts a story that is more romantic than nine novels out of ten, and we have read the book from first to last with unflagging interest."—*Boston Commercial Bulletin.*

ADDRESS DELIVERED BEFORE THE BRITISH ASSOCIATION, assembled at Belfast. By JOHN TYNDALL, F. R. S., President. Revised, with additions, by the author, since the delivery. 12mo. 120 pages. Paper. Price, 50 cents.

This edition of this now famous address is the only one authorized by the author, and contains additions and corrections not in the newspaper reports.

THE PHYSIOLOGY OF MAN. Designed to represent the Existing State of Physiological Science as applied to the Functions of the Human Body. By AUSTIN FLINT, Jr., M. D. Complete in Five Volumes, octavo, of about 500 pages each, with 105 Illustrations. Cloth, $22.00; sheep, $27.00. Each volume sold separately. Price, cloth, $4.50; sheep, $5.50. The fifth and last volume has just been issued.

The above is by far the most complete work on human physiology in the English language. It treats of the functions of the human body from a practical point of view, and is enriched by many original experiments and observations by the author. Considerable space is given to physiological anatomy, particularly the structure of glandular organs, the digestive system, nervous system, blood-vessels, organs of special sense, and organs of generation. It not only considers the various functions of the body, from an experimental stand-point, but is peculiarly rich in citations of the literature of physiology. It is therefore invaluable as a work of reference for those who wish to study the subject of physiology exhaustively. As a complete treatise on a subject of such interest, it should be in the libraries of literary and scientific men, as well as in the hands of practitioners and students of medicine. Illustrations are introduced wherever they are necessary for the elucidation of the text.

D. APPLETON & CO., PUBLISHERS, 549 & 551 Broadway, N. Y.

JUST PUBLISHED.

Money and the Mechanism of Exchange.

Vol. XVII. of the International Scientific Series. By W. Stanley Jevons, M. A., F. R. S., Professor of Logic and Political Economy in the Owens College, Manchester. 1 vol., 12mo. Cloth. Price, $1.75.

"He offers us what a clear-sighted, cool-headed, scientific student has to say on the nature, properties, and natural laws of money, without regard to local interests or national bias. His work is popularly written, and every page is replete with solid instruction of a kind that is just now lamentably needed by multitudes of our people who are victimized by the grossest fallacies."—*Popular Science Monthly.*

"If Professor Jevons's book is read as extensively as it deserves to be, we shall have sounder views on the use and abuse of money, and more correct ideas on what a circulating medium really means."—*Boston Saturday Evening Gazette.*

"Prof. Jevons writes in a sprightly but colorless style, without trace of either prejudice or mannerism, and shows no commitment to any theory. The time is not very far distant, we hope, when legislators will cease attempting to legislate upon money before they know what money is, and, as a possible help toward such a change, Prof. Jevons deserves the credit of having made a useful contribution to a department of study long too much neglected, but of late years, we are gratified to say, becoming less so."—*The Financier, New York.*

Weights, Measures, and Money, of all Nations.

Compiled by F. W. Clarke, S. B., Professor of Physics and Chemistry in the University of Cincinnati. Price, $1.50.

"This work will be found very useful to the merchant, economist, and banker, as the arrangement is highly convenient for reference, and in a form and classification never before presented to the public. It also contains a series of tables, arranged alphabetically, showing the value of each unit as given both in the English and the metric standards. The metric system is used coextensively with the ordinary system, and is a characteristic feature of the book.

"The contents, among other things, contain the following useful and comprehensive tables, viz.: I. Measures of Length, in both the English or American feet or inches, and in French metres. II. Road-Measures in English miles and French kilometres. III. Land-Measures. IV. Cubic Measures. V. Liquid Measures. VI. Dry Measures. VII. Weights, and finally Money. This latter table is one of the most useful and valuable tables probably to be found, giving as it does the standards in dollars, francs, sterling, and marks, and alone is worth the cost of the book."—*N. Y. Commercial and Financial Chronicle.*

"We commend this carefully-prepared and convenient volume to all persons who wish to acquire information on the subject of which it treats."—*Boston Globe.*

"The work necessary to the production of this little volume has been judiciously planned and skillfully executed."—*Chicago Tribune.*

D. APPLETON & CO., Publishers, 549 & 551 Broadway, N. Y.

THE GREAT ICE AGE,

AND ITS RELATIONS TO THE ANTIQUITY OF MAN.

By JAMES GEIKIE, F. R. S. E.

With Maps, Charts, and numerous Illustrations.

1 vol., thick 12mo. . . . Price, $2.50.

OPINIONS OF THE PRESS.

"Intelligent general readers, as well as students of geology, will find more information and reasonable speculation concerning the great glacial epoch of our globe in this volume than can be gathered from a score of other sources. The author writes not only for the benefit of his 'fellow-hammerers,' but also for non-specialists, and any one gifted with curiosity in respect to the natural history of the earth will be delighted with the clear statements and ample illustrations of Mr. Geikie's 'Great Ice Age.'"—*Episcopal Register.*

"'The Great Ice Age' is a work of extraordinary interest and value. The subject is peculiarly attractive in the immensity of its scope, and exercises a fascination over the imagination so absorbing that it can scarcely find expression in words. It has all the charms of wonder-tales, and excites scientific and unscientific minds alike."—*Boston Gazette.*

"Mr. Geikie has succeeded in writing one of the most charming volumes in the library of popularized science."—*Utica Herald.*

"We cannot too heartily commend the style of this book, which is scientific and yet popular, and yet not so popular as to dispense with the necessity of the reader's putting his mind to work in order to follow out the author in his forcible yet lucid arguments. Nor can the attentive reader fail to leave the work with the same enthusiasm over the subject as is shown in every page by the talented author."—*Portland Press.*

"Although Mr. Geikie's position in the scientific world is such as to indicate that he is a pretty safe teacher, some of his views are decidedly original, and he does not make a point of sticking to the beaten path."—*Springfield Union.*

"Prof. Geikie's book is one that may well engage thoughtful students other than geologists, bearing as it does on the absorbing question of the unwritten history of our race. The closing chapter of his work, in which, reviewing his analytical method, he constructs the story of the checkered past of the last 200,000 years, can scarcely fail to give food for thought even to the indifferent."—*Buffalo Courier.*

"Every step in the process is traced with admirable perspicuity and fullness by Mr. Geikie."—*London Saturday Review.*

"It offers to the student of geology by far the completest account of the period yet published, and is characterized throughout by refreshing vigor of diction and originality of thought."—*Glasgow Herald.*

D. APPLETON & CO., Publishers,
549 & 551 BROADWAY, N. Y.

THE EXPANSE OF HEAVEN;

A Series of Essays on the Wonders of the Firmament.

By R. A. PROCTOR, B. A.

1 vol., 12mo. Cloth. . . . . . . Price, $2.00.

"It is Mr. Proctor's good fortune that not only is he one of the greatest of living astronomers, but that he has a power of imparting knowledge that is not equaled by any living astronomer. His style is as lucid as the light with which he deals so largely, and the plainest of readers can go along with him with entire ease, and comprehend all that he says on the grandest subject ever discussed by mortal intelligence. Most scientific writers either cannot or will not so use the pen as to make themselves understood by the many; not so with Mr. Proctor: he both can and does so write as to command the attention of the million, and this too without in the least derogating from the real dignity of his sublime theme. Few of us can study astronomy, because that implies a concentrated devotion to an inexhaustible matter, but we all can read astronomical works to our great advantage if astronomers who write will but write plainly; and in that way, without having the slightest claim to be spoken of as "scientists," we can acquire no ordinary amount of knowledge concerning things that are of the loftiest nature, and the effect of which must be to elevate the mind. Such a book as 'The Expanse of Heaven' cannot fail to be of immense use in forwarding the work of education even when it is read only for amusement, so forcible is the impression it makes on the mind from the importance of the subjects treated of, while the manner of treatment is so good."—*Boston Traveller.*

"Since the appearance of Ennis's book on 'The Origin of the Stars,' we have not read a more attractive work on astronomy than this. It is learned enough to be instructive, and light enough to be very entertaining."—*Alta California.*

"It reads like a work of fiction, so smooth and consecutive is it; but it inspires the worthiest thoughts and the highest aspirations."—*Boston Commonwealth.*

"Perfectly adapted to their purposes, namely, to awaken a love for science, and at the same time to convey, in a pleasant manner, some elementary facts."—*Church Herald.*

"This is not a technically scientific work, but an expression of a true scholar's conception of the vastness and grandeur of the heavens. There is no dry detail, but blended with the scholar's discoveries are the poet's thoughts, and a true recognition of the Almighty's power."—*Troy Times.*

D. APPLETON & CO., Publishers,
549 & 551 BROADWAY, N. Y.

THE POPULAR SCIENCE MONTHLY.

CONDUCTED BY

E. L. YOUMANS.

This periodical was started (*in* 1872) *to promote the diffusion of valuable scientific knowledge, in a readable and attractive form, among all classes of the community, and has thus far met a want supplied by no other magazine in the United States.*

Eight volumes have now appeared, which are filled with instructive and interesting articles and abstracts of articles, original, selected, translated, and illustrated, from the pens of the leading scientific men of different countries. Accounts of important scientific discoveries, the application of science to the practical arts, and the latest views put forth concerning natural phenomena, have been given by *savants* of the highest authority. Prominent attention has been also devoted to those various sciences which help to a better understanding of the nature of man, to the bearings of science upon the questions of society and government, to scientific education, and to the conflicts which spring from the progressive nature of scientific knowledge.

THE POPULAR SCIENCE MONTHLY has long since ceased to be an experiment. It has passed into a circulation far beyond the most sanguine hopes at first entertained, and the cordial and intelligent approval which it has everywhere met, shows that its close and instructive discussions have been well appreciated by the reading portion of the American people. It has not been its policy to make boastful promises of great things to be done in the future, but rather to appeal to what it has already accomplished as giving it a claim upon popular patronage. But no pains will be spared to improve it and make it still more worthy of liberal support, and still more a necessity to the cultivated classes of the country.

THE POPULAR SCIENCE MONTHLY is published in a large octavo, handsomely printed on clear type, and, when the subjects admit, fully illustrated. Each number contains 128 pages.

Terms: $5 per Annum, or Fifty Cents per Number.

Postage free to all Subscribers in the United States, from January 1, 1875.

A new volume of THE POPULAR SCIENCE MONTHLY begins with the numbers for May and November each year. Subscriptions may commence from any date. Back numbers supplied.

Now Ready, Vols. I., II., III., IV., V., VI., VII., and VIII., of the Popular Science Monthly, embracing the numbers from 1 to 48 (May, 1872, to April, 1876). 8 vols., 8vo. Cloth, $3.50 per vol. Half Morocco, $6.50 per vol.

For Sale, Binding Cases for Vols. I., II., III., IV., V., VI., VII., and VIII., of The Popular Science Monthly. These covers are prepared expressly for binding the volumes of THE POPULAR SCIENCE MONTHLY as they appear, and will be sent to Subscribers on receipt of price. Any binder can attach the covers at a trifling expense. Price, 50 cents each.

ADDRESS *D. APPLETON & CO., Publishers,*

549 & 551 Broadway, New York.